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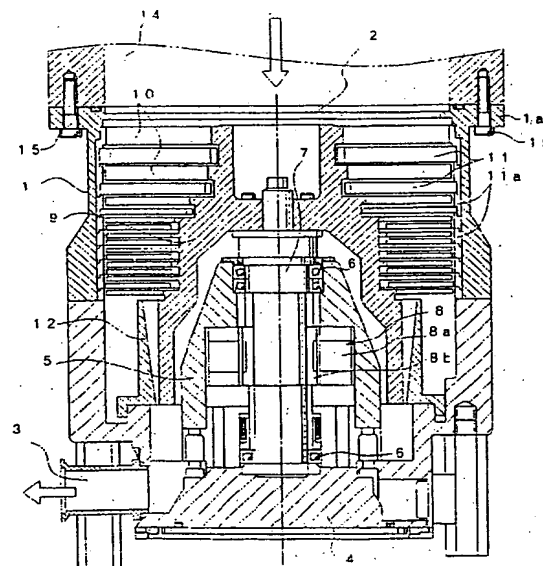
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(54) **Vacuum pump**

(57) A vacuum pump has a pump case (1) with a gas suction port (2) at the upper surface thereof and a gas exhaust port (3) at the lower part thereof; a stator column (5) disposed in the pump case as so to be erected; a flange (1a) formed along the circumferential top of the pump case; a rotor shaft (7) disposed in the center of the stator column; a rotor (9) rotatably supported by the stator column via the rotor shaft; a rotor blade (10) fixed to the circumferential outer surface of the rotor; a stator blade (11) fixed to the circumferential inner surface of the pump case such that the rotor blade and the stator blade are alternately disposed; a driving motor (8) disposed between the rotor shaft and the stator column; and bolts for connecting the flange to the a chamber. The flange includes bolt insertion holes (15), each having plural steps which increase in size step by step toward the chamber.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to vacuum pumps used in semiconductor manufacturing apparatus, and more particularly, the present invention relates to the structure of a vacuum pump for preventing a brittle fracture of a fastening bolt that connects the vacuum pump and a process chamber, which is caused by a damaging torque.

2. Description of the Related Art

[0002] In a process such as dry etching, chemical vapor deposition (CVD), or the like performed in a high-vacuum process chamber in semiconductor manufacturing step, a vacuum pump such as a turbo-molecular pump is used for producing a high vacuum in the process chamber by exhausting gas from the process chamber.

[0003] Fig. 1 illustrates the basic structure of such a vacuum pump. As shown in Fig. 1, the vacuum pump has a cylindrical pump case 1 having a bottom, and the pump case 1 has an opening at the top portion thereof serving as a gas suction port 2 and an exhaust pipe, at a lower part of the cylindrical surface thereof, serving as a gas exhaust port 3.

[0004] The bottom portion of the casing 1 is covered with an end plate 4, and a stator column 5 is provided so as to be erected at the center portion of internal bottom surface thereof.

[0005] A rotor shaft 7 rotatably supported by an upper ball bearing 6 and a lower ball bearing 6 at the center of the stator column 5.

[0006] A driving motor 8 is arranged inside the stator column 5. The driving motor 8 has a structure in which a stator element 8a is disposed on the rotor shaft 7, and it is structured such that the rotor shaft 7 is rotated about the shaft.

[0007] A rotor 9, which covers the outer circumference of the stator column 5 and is formed in a section-shape, is connected to the upper portion protrusion end from the stator column 5 of the rotor shaft 7.

[0008] A plurality of rotor blades 10 is disposed and fixed to the upper part of the circumferential outer surface of the rotor 9, while a plurality of stator blades 11 and a plurality of rotor blades 10 are alternately disposed and fixed each other inside of the pump case 1 via ring spacers 11a.

[0009] The pump case 1 has a threaded stator 12 is disposed and fixed under the blades 10 and 11 and around the rotor 9. The threaded stator 12 is formed to be a tapered cylindrical shape so as to surround the outer circumferential surface of the lower part of the rotor 9 and is formed its inner surface to be tapered shape,

the inner surface of which diameter gradually decreases downwardly. Also, the threaded stator 12 has thread grooves formed on the tapered inner surface thereof.

[0010] A flange 1a is formed along the circumferential uppermost portion of the pump case 1. The flange 1a is fitted on the peripheral end of opening portion of the lower surface side of a process chamber (hereinafter, referred to as "chamber") 14 and a plurality of fastening bolts 15, which penetrate the flange 1a, are screwed in and fixed to the chamber 14, so that the pump case 1 is connected to the chamber 14.

[0011] Next, the operation of the foregoing vacuum pump will be described. In this vacuum pump, firstly, an auxiliary pump (not shown) connected to the gas exhaust port 3 is activated so as to evacuate the chamber 14 to a certain vacuum level. Then, the driving motor 8 is operated so as to rotate the rotor shaft 7, the rotor 9 connected to the rotor shaft 7, and the rotor blades 10 also connected to the rotor shaft 7 are rotated at high speed.

[0012] When the rotor blade 10 rotating at high speed at the uppermost stage, the rotor blade 10 imparts a downwards momentum to the gas molecules to entering through the gas suction port 2, the gas molecules with this downwards momentum are guided by the stator blades 11 to be transferred to the next lower rotor blade 10 side. By repeating this imparting of momentum to the gas molecules and transferring operation, the gas molecules are transferred from the gas suction port 2 to the inside of the thread stator 12 provided on the lower portion side of the rotor 2 in order. The above-described operation of exhausting gas molecules is called a gas molecule exhausting operation performed by the interaction between the rotating rotor blades 10 and the stationary stator blades 11.

[0013] The gas molecules reaching to the thread stator 12 by the above-described gas molecule exhausting operation are compressed from a intermediate flow state to a viscous flow state, are transferred toward the gas exhaust port 3 by the interaction between the rotating rotor 9 and the thread grooves formed inside the thread stator 12 and are eventually exhausted to the outside via the gas exhaust port 3 by the auxiliary pump (not shown).

[0014] Incidentally, as structural materials of the casing 1, the rotor 9, the rotor blade 10 and the stator blade 11 or the like, which compose the vacuum pump, light alloy, in particular, aluminum alloy is normally employed in many cases. This is because aluminum alloy is excellent in machining and can be precisely processed without difficulty. However, the hardness of aluminum alloy relatively low as compared with other materials and aluminum alloy may cause a creep fracture depending on the operating condition. Further, a brittle fracture may occur in operation mainly caused by a stress concentration at the lower part of the rotor 9.

[0015] If the brittle fracture occurs in the rotor 9 during a high speed rotation, some of the rotor blades 10 inte-

grally formed with the circumferential outer surface of the rotor 9 crash into the ring spacers 11a disposed on the circumferential inner surface of the pump case 1. Since the ring spacers 11a have insufficient strength against this smashing force, the smashing force causes the ring spacers 11a to expand in the radial direction thereof. When a sufficient clearance is not provided between the ring spacers 11a and the circumferential inner surface of the pump case 1, the expanded ring spacers 11a come into contact with the circumferential inner surface of the pump case 1, thereby producing a large damaging torque which causes the whole pump case 1 to rotate, and accordingly, this damaging torque causes the chamber 14 to be broken or the torsional moment due to the damaging torque causes the bolts 15 fastening the pump case 1 to the chamber 14 to be broken by shearing.

[0016] Since such a damaging torque causes the contact surface of the flange 1a of the pump case 1 with the chamber 14 to act as a sliding surface and two very large forces to be instantaneously exerted on a portion, lying in the vicinity of the contact surface, of the bolt shaft of each bolt 15 in opposite directions, the bolt 15 is easily broken at the foregoing portion acting as a breaking surface, thereby leading to the above-described shearing breakage. Once the bolt 15 is broken, since its bolt shaft cannot be extracted from the corresponding hole of the chamber 14, the bolt shaft left in the chamber 14 must be removed by tapping. Also, replacing the damaged vacuum pump with a new one is troublesome.

[0017] The present invention is made so as to solve the above-described problems. It is an object of the present invention to provide a vacuum pump which prevents a chamber and fastening bolts, connecting the pump to the chamber, from being broken even when a damaging torque occurs caused by a trouble in the pump, and which can be quickly replaced with a new one.

SUMMARY OF THE INVENTION

[0018] To attain the above described object, a vacuum pump according to the present invention comprises a pump case including a gas suction port formed at an upper surface of the pump case and a gas exhaust port formed at a lower part of the cylindrical surface of the pump case; a rotor rotatably supported by a stator column via a rotor shaft, wherein the rotor is provided with a rotor blade fixed to the circumferential outer surface of the rotor and the stator column is provided so as to be erected in the pump case; a stator blade alternately fixed and positioned with the rotor shaft to the circumferential inner surface of the pump case; a driving motor disposed between the rotor shaft and the stator column; a plurality of bolts for connecting a flange to the circumferential bottom portion of a chamber, wherein the flange is formed along the circumferential top portion of the pump case; a plurality of bolt insertion holes having

stages which increase in size step by step toward the fixing surface of the chamber.

[0019] In the vacuum pump having the above-described structure according to the present invention, when the damaging torque is generated, the shearing force at the upper edge of each step caused by the damaging torque moves upwards step by step and does not concentrate on one specific upper edge, and the shock caused by the damaging torque is absorbed during this time period. As a result, the bolt shaft of the bolt merely undergoes a plastic deformation, thereby preventing the damaging torque from being transferred to the chamber so that the chamber is prevented from being damaged, and also preventing the bolt from being broken.

[0020] The vacuum pump according to the present invention may further comprise a buffer member disposed between the inner wall of the bolt insertion hole and the bolt shaft of the corresponding bolt. With this structure, the buffer effect of the elastically deformed buffer member prevents the damaging torque from being transferred to the chamber so that the chamber is prevented from being damaged, and also prevents the bolt from being broken.

[0021] The vacuum pump according to the present invention may have a structure in which the bolt insertion hole may have two steps having large and small diameters and the buffer member may be disposed between the bolt shaft and the large step portion close to the chamber.

[0022] Alternatively, the vacuum pump may further comprise a washer disposed between the bolt head and the flange, and has a structure in which the buffer member has a insertion hole for the bolt shaft to pass there-through, and the bolt shaft and the upper part of the buffer member having an enlarged inner diameter have a gap therebetween.

[0023] Still alternatively, the vacuum pump may have a structure in which the bolt insertion hole has a tapered shape which increases in size toward the fixing surface of the chamber and the buffer member having a truncated cone shape is disposed between the bolt shaft and the bolt insertion hole.

[0024] A variety of devised shapes and structures of the buffer members disposed between the bolt shaft and the bolt insertion hole prevent the damaging torque from being transferred to the chamber so that the chamber may be prevented from being damaged, and also prevent the bolt from being broken.

[0025] In the vacuum pump according to the present invention, the bolt is preferably an extending bolt comprising a reduced-diameter portion between the bolt head and the male-threaded portion thereof and the diameter of the reduced-diameter portion is preferably smaller than the root diameter of the male-threaded portion.

[0026] In the vacuum pump according to the present invention, the extending bolt is preferably screwed into the chamber such that the top of the reduced-diameter

portion enters the chamber by the length of one or two threads of the bolt.

[0027] In the vacuum pump according to the present invention, the buffer member may be composed of a rubber material.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028]

Fig. 1 is a front sectional view of the entire structure of a vacuum pump according to the present invention;

Fig. 2 is a partial front view in section illustrating the connecting structure of a flange and a chamber of a vacuum pump according to a first embodiment of the present invention;

Figs. 3(a) to 3(c) are partial front views in section illustrating a process in which a damaging torque is generated;

Fig. 4 is a partial front view in section illustrating a second embodiment according to the present invention;

Fig. 5 is a partial front view in section illustrating a modification of the second embodiment according to the present invention;

Fig. 6 is a partial front view in section illustrating another modification of the second embodiment according to the present invention;

Fig. 7 is a front view of an extending bolt used for connecting the flange to the chamber according to the present invention;

and

Fig. 8 is a partial front view in section illustrating an example of the extending bolt shown in Fig. 7 applied to to the second embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0029] Vacuum pumps according to preferred embodiments of the present invention will be described in further detail with reference to the accompanying drawings. Since basic structure of a vacuum pump is same as that of the conventional pump shown in Fig. 1. Therefore, the entire explanation will be omitted and the same numerals and symbols will be used designate the same component and the different symbols will be employed to designate only the necessary components in the description.

[0030] Figs. 2 and 3 shows a first embodiment of a vacuum pump according to the present invention, wherein those Figures shows a partial front view in section of a flange 1a and Fig. 2 shows the structure of the first embodiment 1a and Figs. 3(a) to 3(c) shows a process thereof

[0031] The bolt 15 is of a commonly used type formed of stainless steel and has a hexagon-socket bolt head

15a and a bolt shaft 15b integrated with the bolt head 15a. The bolt shaft 15b has a male-threaded portion formed thereon so as to have a given thread pitch.

[0032] The chamber 14 has a plurality of female-threaded portions 14a formed in the circumferential fixing portion thereof along the circumferential upper surface of the flange 1a. Each female-threaded portion 14a has the same thread pitch as that of the male-threaded portion formed on the bolt shaft 15b.

[0033] Although the figures illustrate only one connecting structure, the number of the fastening bolts 15 is in the order of 8 to 12 depending on the diameter of the pump case 1 and the corresponding number of the female-threaded portions 14a are formed in the fixing portion of the chamber 14 at a same interval in the circumferential direction of the flange 1a.

[0034] A bolt insertion hole 20 is formed in the flange 1a so as to correspond to the female-threaded portions 14a. The cross section of the bolt insertion hole 20 has three steps 20a, 20b, and 20c having greater diameters step by step toward the fixing surface of the flange 1a in this embodiment. The first step 20a has a diameter d_1 , the same as that of a typical bolt insertion hole, the second step 20b has a diameter d_2 slightly greater than d_1 , and the third step 20c has the maximum diameter d_3 .

[0035] In the vacuum pump having the above-described structure, when some kind of problem occurs and thus causes breaking forces F and F' , which are equal to each other but act in the opposite directions, to be produced in the pump case 1 in the circumferential direction thereof, first, as shown in Fig. 3(a), the flange 1a moves in the circumferential direction thereof due to the forces F and F' which are greater than the fastening force of the bolt 15. As a result, the bolt shaft 15b abuts against the inner wall of the first step 20a of the insertion hole 20 and then the bolt shaft 15b is bent at a contact point CP1 contacting with the upper edge of the first step 20a due to a shearing force produced at the contact point CP1. Then, as shown in Fig. 3(b), the bolt shaft 15b is further bent at a contact point CP2 contacting with the upper edge of the second step 20b.

[0036] Furthermore, as shown in Fig. 3(c), the bolt shaft 15b is further bent at a contact point CP3 contacting with the upper edge of the third step 20c and also experiences a shearing force produced by the mutual slide between the fixing surfaces of the flange 1a and the chamber 14.

[0037] Although the above-described movement occurs instantaneously, since the bolt shaft 15b experiences bending moments in a time sequential manner at the three points from the steps 20a to 20c, and also at the fixing surfaces, the shearing forces due to the bending moment do not concentrate on one point of the bolt shaft. Also, the flange 1a absorbs a shock by moving in the circumferential direction thereof during this time period of operation. Since the bolt shaft 15b simply experiences a plastic deformation as shown in Fig. 3(c), the

above-described structure prevents the transfer of the damaging torque to the chamber 14, thereby preventing the chamber 14 from being damaged and also the breaking of the bolt 15. Accordingly, the damaged vacuum pump can be quickly replaced with a new one without tapping since the broken bolt 15 can be extracted from the chamber 14 by using, for example, a wrench.

[0038] In the first embodiment shown in Figs. 2 to 3 (c), a buffer member having a large diameter shown in Fig. 4, which will be described later, or another buffer member filling the overall gap between the bolt 15 and the bolt insertion hole 20 may be used.

[0039] Figs. 4 to 6 show the second embodiment, using a buffer member, and the modifications according to the second embodiment.

[0040] As shown in Fig. 4, a bolt insertion hole 30 formed in the flange 1a has two steps, i.e., a small-diameter step 30a and a large diameter step 30b on the step 30a, and a cylindrical buffer member 31 is filled in the gap between the large step portion 30b and the bolt shaft 15b. The buffer member 31 is formed of a rubber material or the like used for an O-ring.

[0041] In the second embodiment shown in Fig. 4, when the damaging torque is generated, the shearing forces exerted on the bolt shaft 15b are dispersed because the bolt shaft 15b contacts the upper edge of the small-diameter step 30a and then the upper edge of the large-diameter step 30b in a similar fashion to that in the first embodiment, and additionally, the elastically deformed buffer member 31 provides a buffer effect. As a result, the above-described dispersion of the shearing forces and buffer effect prevent the transfer of the damaging torque to the chamber 14, thereby preventing the chamber 14 from being damaged and also the bolt 15 from being broken.

[0042] Fig. 5 shows a modification according to the second embodiment. As shown in Fig. 5, a large-diameter bolt insertion hole 40 having a straight cylindrical wall is formed in the flange 1a and the bolt shaft 15b passes through the bolt insertion hole 40 having a buffer member 41 interposed therebetween. Also, the male-threaded portion of the bolt shaft 15b is screwed in and fixed to the female-threaded portion 14a of the chamber 14. The straight cylindrical buffer member 41, which is forced and fitted into the bolt insertion hole 30, has an upper portion having an inner diameter larger than the diameter of the bolt shaft 15b so as to form a predetermined gap d between the foregoing upper portion and the bolt shaft 15b. In addition, a flat washer 42 is interposed between the bolt head 15a and the flange 1a so as to increase a contact area of the bolt head 15a with the flange 1a via the flat washer 42.

[0043] According to the modification shown in Fig. 5, in addition to a buffer effect due to the elastic deformation of the buffer member 41, the gap d formed around the upper portion of the bolt shaft 15b provides the bolt shaft 15b with a sufficient space for the plastic deformation, and the flat washer 42 lying between the bolt head

15a and the bolt insertion hole 40 allows the bolt 15 to move. Accordingly, the above-described structure prevents the transfer of the damaging torque to the chamber 14, thereby preventing the chamber 14 from being damaged and also the breaking of the bolt 15.

[0044] As shown in Fig. 6 illustrating the other modification, a bolt insertion hole 50 having an upwardly-enlarging tapered shape is formed in the flange 1a, and a buffer member 51 having a truncated cone shape is filled in the gap between the bolt insertion hole 50 and the bolt shaft 15b.

[0045] According to the other modification shown in Fig. 6, since the buffer member 50 having a geometrical shape along which the bolt shaft 15b is likely deformed due to an assumed bending moment is disposed in the above-described manner, the buffer member 50 provides the bolt shaft 15b with a uniform buffer effect along its deformed portion. Accordingly, the above-described structure prevents the transfer of the damaging torque to the chamber 14, thereby preventing the chamber 14 from being damaged and also the bolt 15 from being broken.

[0046] In the connecting structure shown in Fig. 6, the buffer member 51 may be eliminated.

[0047] Next, the use of an extending bolt for connecting the flange 1a to the chamber 14 according to the present invention will be described below with reference to Figs. 7 and 8.

[0048] As is well known, the extending bolt shown in Fig. 7 has a reduced-diameter portion 15d, as a part of the bolt shaft 15b, between the bolt head 15a and the male-threaded portion 15c. The diameter of the reduced-diameter portion 15d is formed so as to be smaller than the root diameter of the male-threaded portion 15c such that the reduced-diameter portion 15d extends so as to prevent components in the vicinity of the bolt from being damaged when an extraordinary load is exerted on the bolt.

[0049] By using this extending bolt as the fastening bolt 15, the transfer of the damaging torque and the breaking of the bolt are further reliably prevented.

[0050] Fig. 8 shows an example of using an extending bolt. The way of preventing the transfer of the damaging torque and the breaking of the bolt by using the extending bolt 15 will be described in reference to Fig. 8. The extending bolt 15 is screwed into the female-threaded portion 14a of the chamber 14 such that the top of the reduced-diameter portion 15d enters the chamber 14 by the length of one or two threads of the bolt 15. The reduced-diameter portion 15d and the female-threaded portion 14a of the chamber 14 have a space therebetween. When the damaging torque is exerted on the flange 1a in this state, although the extending bolt 15 experiences shearing and tensile forces in a similar fashion to that shown in Fig. 3, the reduced-diameter portion 15d of the extending bolt 15 extends and bends in a spacious bolt insertion hole 20. In an extraordinary case, the reduced-diameter portion 15d is broken. Ac-

cordingly, the portions of the bolt 15 other than the reduced-diameter portion 15d, including the male-threaded portion 15c, are not deformed and the kinetic energy due to the damaging torque is absorbed by the deformation of the reduced-diameter portion 15d of the extending bolt 15.

[0051] As a result, the male-threaded portion 15c and the female-threaded portion 14a are not deformed at all, thereby allowing the broken fastening bolt 15 to be easily extracted from the female-threaded portion 14a of the chamber 14.

[0052] Also in the embodiment shown in Fig. 8, a buffer member can be filled in the upper part or the entire part of the gap between the extending bolt 15 and the bolt insertion hole 20.

[0053] As is seen from the above description, since the vacuum pump according to the present invention has a structure in which the bolt insertion hole formed in the flange has a plurality of steps which increase in size towards the top step by step, damage to the chamber caused by the damaging torque transferred to the chamber can be prevented and also the breaking of the bolt for connecting the vacuum pump to the chamber can be prevented, thereby allowing the damaged vacuum pump to be quickly replaced with a new one.

Claims

1. A vacuum pump comprising:

a pump case (1) including a gas suction port (2) formed at an upper surface of the pump case and a gas exhaust port (3) formed at a lower part of the cylindrical surface of the pump case; a rotor (9) rotatably supported by a stator column (5) via a rotor shaft (7), wherein the rotor is provided with a rotor blade (10) fixed to the circumferential outer surface of the rotor and the stator column is provided so as to be erected in the pump case; a stator blade (11) alternately fixed and positioned with the rotor shaft to the circumferential inner surface of the pump case, a driving motor (8) disposed between the rotor shaft and the stator column; a plurality of bolts (15) for connecting a flange (1a) to the circumferential bottom portion of a chamber (14), wherein the flange is formed along the circumferential top portion of the pump case; a plurality of bolt insertion holes (30, 40, 50) having stages which increase in size step by step toward the fixing surface of the chamber.

2. The vacuum pump according to Claim 1, further comprising a buffer member (31, 41, 51) disposed between the bolt insertion hole bored at the flange

and the bolt shaft of the corresponding bolt.

3. The vacuum pump according to Claim 2, wherein the bolt insertion hole has two steps having large and small diameters and the buffer member is disposed between a bolt shaft (15b) and the large step portion close to the chamber.
4. The vacuum pump according to Claim 2, further comprising a washer (42) disposed between a bolt head (15a) and the flange, wherein the buffer member has a insertion hole for the bolt shaft to pass therethrough, and the bolt shaft and the upper part of the buffer member having an enlarged inner diameter have a gap (d) therebetween.
5. The vacuum pump according to Claim 2, wherein the bolt insertion hole has a tapered shape which increases in size toward the fixing surface of the chamber and the buffer member having a truncated cone shape is disposed between the bolt shaft and the bolt insertion hole.
6. The vacuum pump according to Claim 1, wherein the bolt is an extending bolt comprising a reduced-diameter portion between the bolt head and a male-threaded portion (15c) thereof and the diameter of a reduced-diameter portion (15d) is smaller than the root diameter of the male-threaded portion.
7. The vacuum pump according to Claim 6, wherein the extending bolt is screwed into the chamber such that the top of the reduced-diameter portion enters the chamber by the length of one or two threads of the bolt.
8. The vacuum pump according to Claim 2, wherein the buffer member consists of a rubber material.

FIG. 1

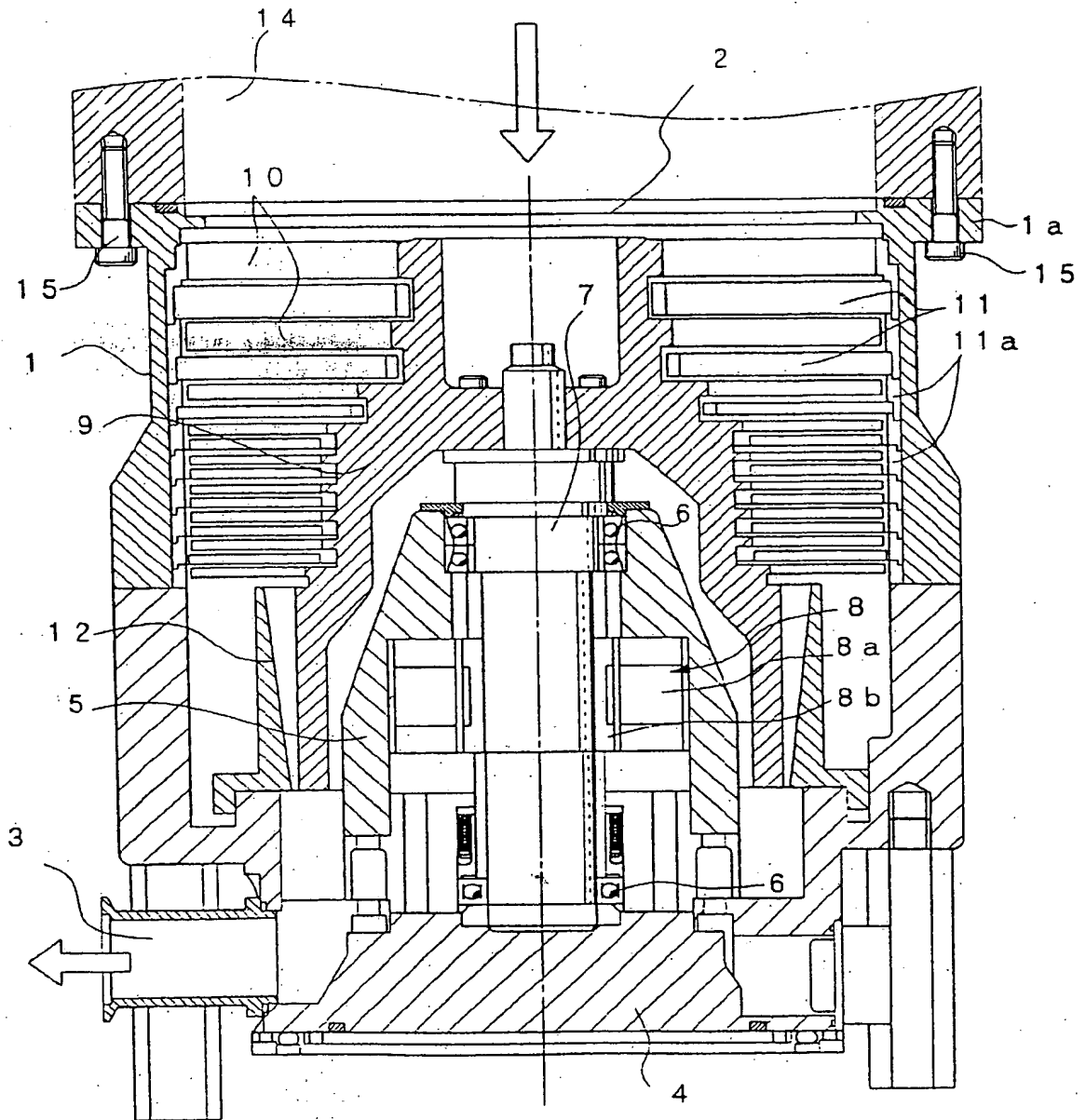


FIG. 2

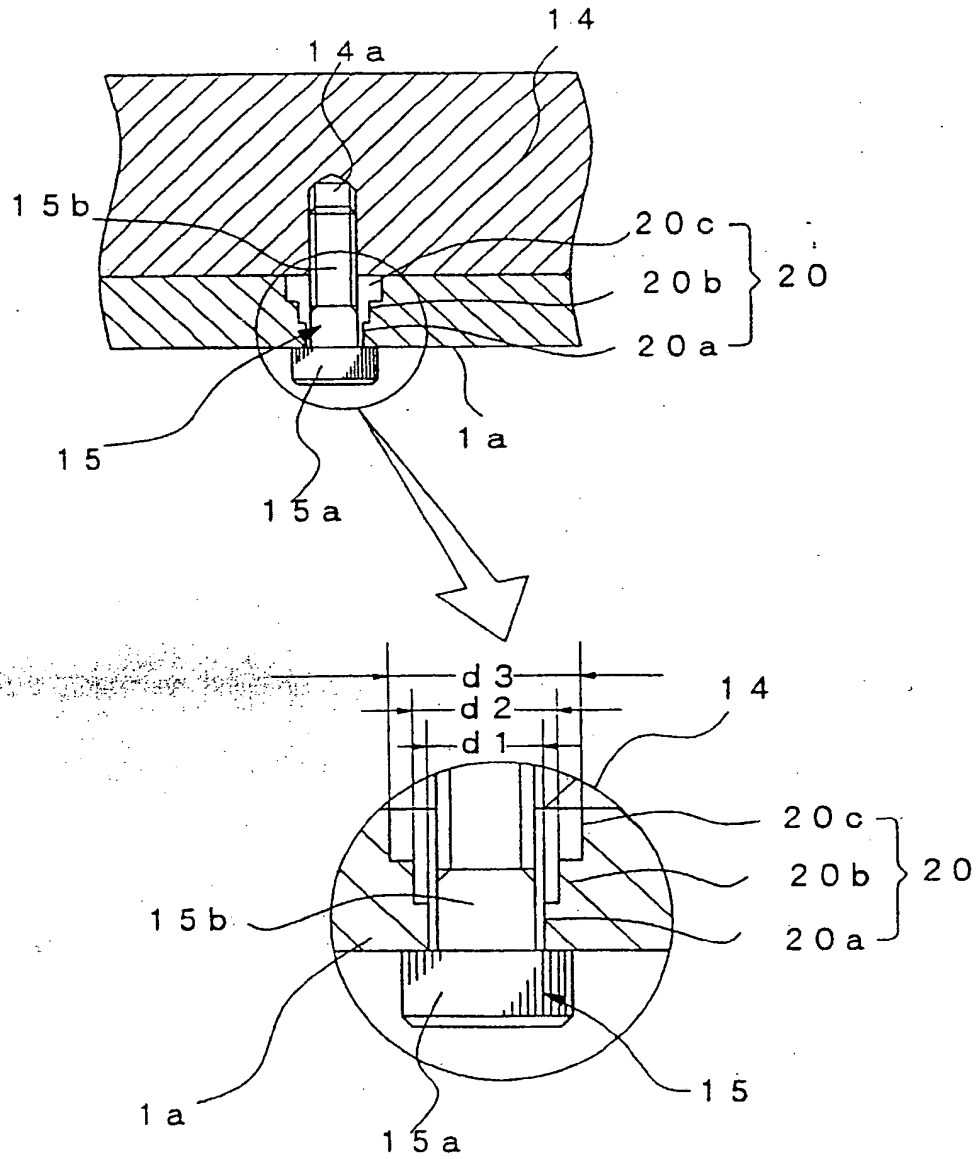


FIG. 3

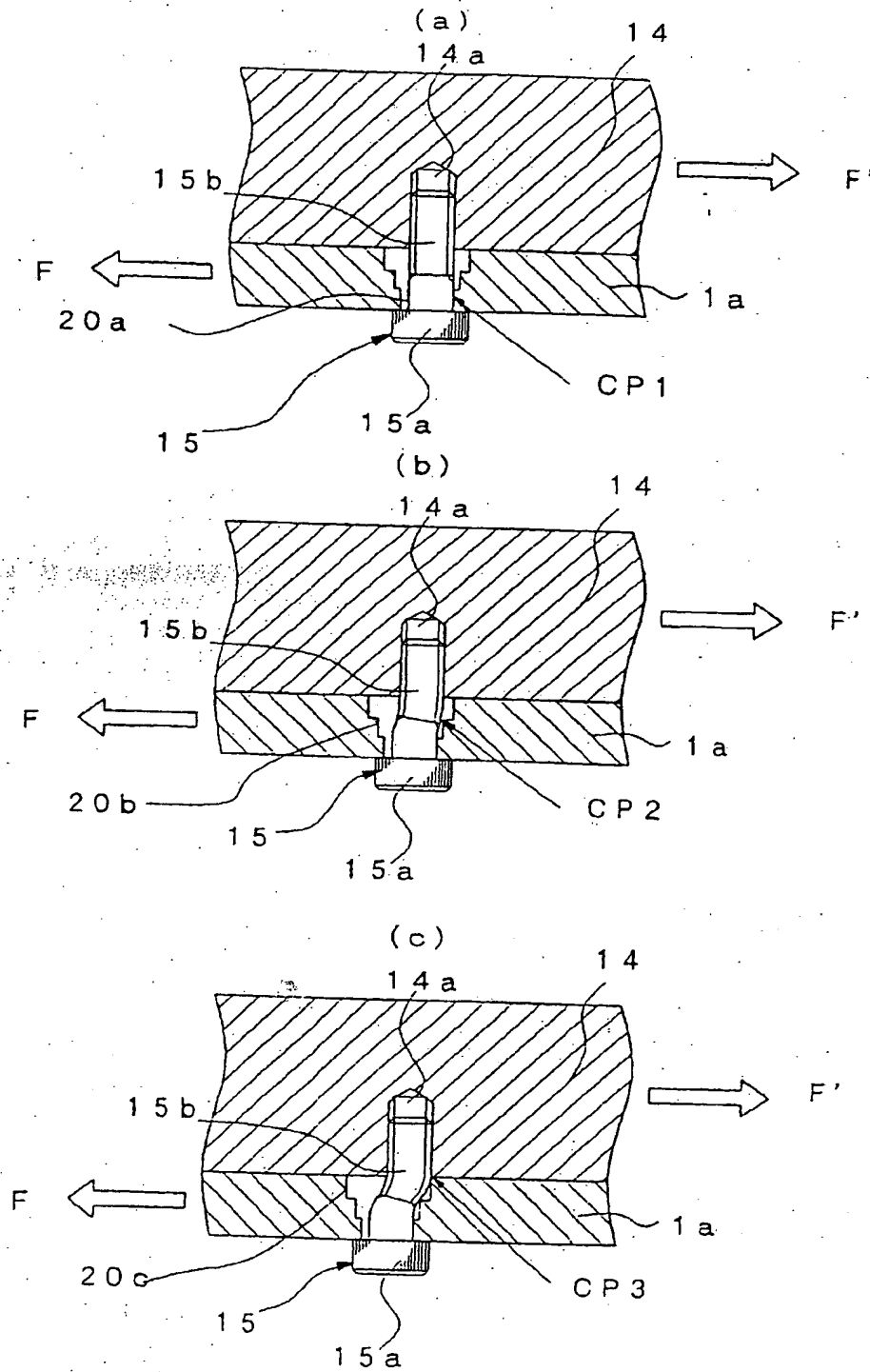


FIG. 4

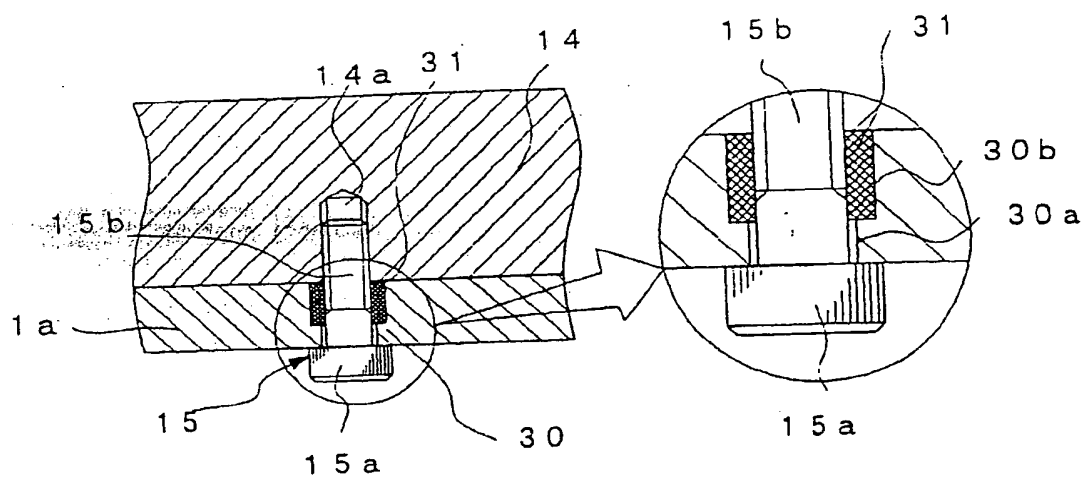


FIG. 5

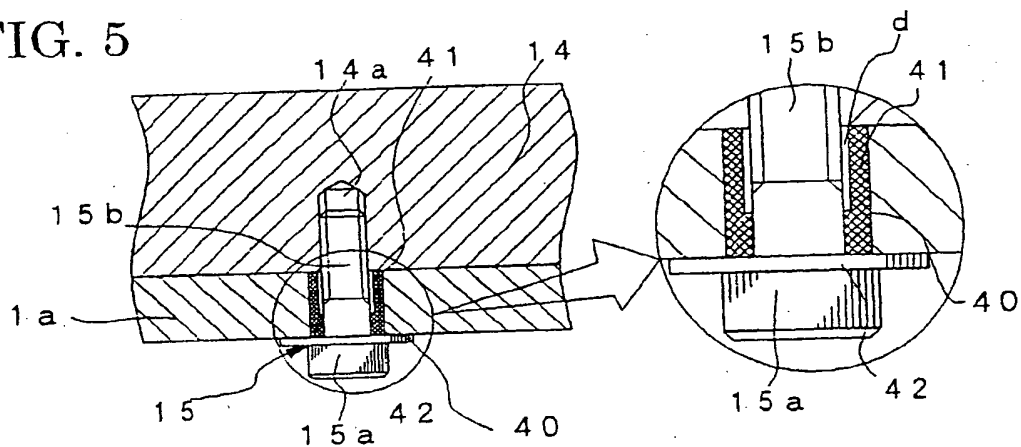


FIG. 6

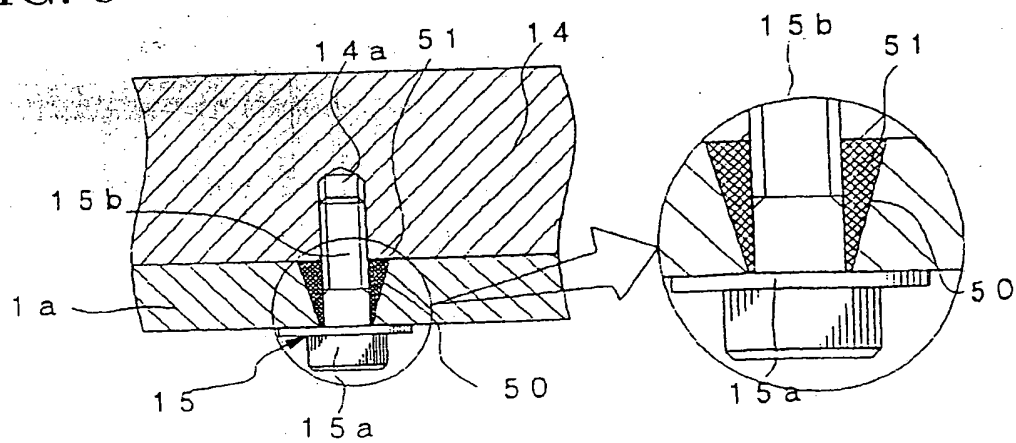


FIG. 7

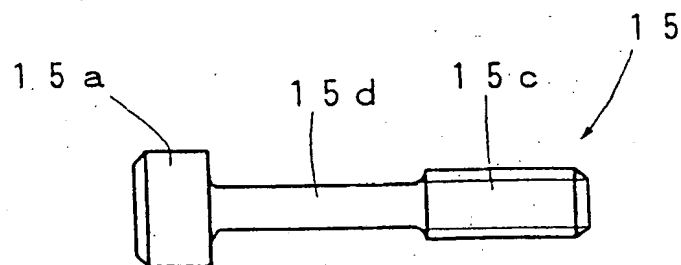
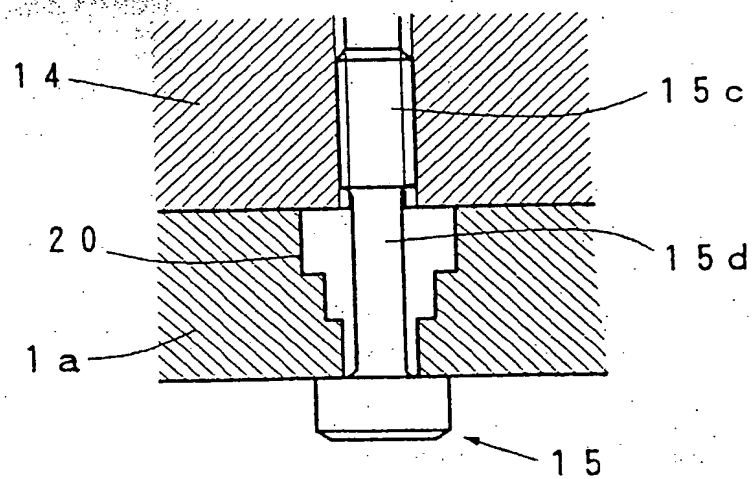


FIG. 8





European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 02 25 7662

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 7 January 2003	Examiner Olona Laglera, C
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